ACE-ASIA COMMUNITY SHIPBOARD FACILITIES AND AEROSOL INLET CHARACTERIZATION

Timothy S. Bates and David S. Covert
Co-Principal Investigators
NOAA/PMEL and the University of Washington

Abstract:
Shipboard measurements during the 2001 ACE-Asia (http://saga.pmel.noaa.gov/aceasia/) intensive field operations will contribute to the regional characterization of aerosol properties by providing data downwind of the continent. Ship operations will be directed to sample regional aerosol features (e.g. dust outbreaks, urban and industrial plumes) under different synoptic meteorological patterns and at various distances from shore. The goals of these studies are to:

- determine the physical, chemical and radiative properties of the aerosol in the ACE-Asia region and assess the vertical, regional and temporal (diurnal to multi-day) variability of these properties,
- assess the major processes controlling the oxidation mechanisms of aerosol precursor gases and the formation, evolution and deposition of aerosol particles, and
- quantify the effect of the combined natural and anthropogenic aerosol on the region's radiation budget.

Accomplishing these goals will require high quality in-situ measurements of aerosol properties. As of January 21, 2000, 25 research groups (http://saga.pmel.noaa.gov/aceasia/us_ship.html) have proposed to join the shipboard component of ACE-Asia. Many of these groups will require space near the bow of the ship for equipment and/or pumps. Many also will need access to an inlet capable of efficiently passing particles over the size range of 5 to 10,000 nm diameter. The purpose of this proposal is twofold. First, we propose to characterize the transmission efficiency of our aerosol sampling mast using the Kirsten Wind Tunnel at the University of Washington. Second, we propose to duplicate our present aerosol sampling mast (or a more efficient variation of that mast) and to outfit a laboratory container and pump container to provide the inlet and space needed by the various research groups proposing to make aerosol measurements on the ship.

Several benefits will be derived from this work.

- The added sampling/pump space will allow more research groups to participate aboard the ship and will thus allow us to more fully characterize aerosol properties and assess the processes controlling those properties.
- The addition of a second identical sampling mast will mean that all in-situ aerosol instruments are sampling the same aerosol population, collected from the same height above sea-level, at the same location on the ship, and at the same flow rate. Our data sets should therefore be directly comparable which will allow us to assess the internal consistency of our data set.
- Quantifying the transmission efficiency of the inlet is critical for comparing the ship data with other platforms and for comparing the in-situ measurements with column integrated aerosol and radiation measurements.

PROPOSED PROJECT DESCRIPTION:

The Asian Pacific Regional Aerosol Characterization Experiment (ACE-Asia) is the fourth of a series of experiments that will quantify the combined chemical and physical processes controlling the evolution and properties of the atmospheric aerosol relevant to radiative forcing and climate (http://saga.pmel.noaa.gov/aceasia/). The objectives of this series of field experiments are to provide the necessary data to incorporate aerosols into global climate models and to reduce the overall uncertainty in the calculation of climate forcing by aerosols. The goal of ACE-Asia is to determine the chemical, physical, and optical characteristics and quantify the controlling processes of the aerosol over the polluted Asian Pacific region. This is an area strongly impacted by the anthropogenic aerosols originating in the rapidly developing Eastern Asian countries.

In-situ measurements of aerosol properties are essential for improving estimates of climate forcing by aerosols (IPCC, 1996). This is the case for both satellite retrievals and model calculations. Inherent in satellite retrievals is the use of an aerosol model that assumes certain aerosol physical, chemical, and optical properties (e.g., Mishchenko et al., 1999). The accuracy of the retrieved aerosol properties depends on the accuracy of the assumed aerosol model. The use of time-dependent regional models built upon a knowledge of regional aerosol properties is expected to improve the accuracy of satellite retrievals (Mishchenko et al., 1999). Chemical transport models produce global aerosol distributions. Initiation and validation of the models with regionally measured aerosol properties are needed to ensure model accuracy. Radiative transfer models require values for aerosol optical properties such as the light scattering efficiency per unit aerosol mass (α_{sp}), the upward scattered fraction ($\overline{\beta}$) or asymmetry factor (g), the fraction of light scattered versus that absorbed or single scattering albedo (ω_o) and the dependence of scattering by the aerosol on relative humidity (f_{sp}(RH)). All these properties depend on the chemical composition, size distribution, morphology and state of the mixture of the aerosol. In-situ measurements of aerosol chemical and physical properties, including mass distributions of the dominant chemical species, the degree of mixing of various chemical species, and the number size distribution, are thus needed to link global aerosol distributions with aerosol optical properties.

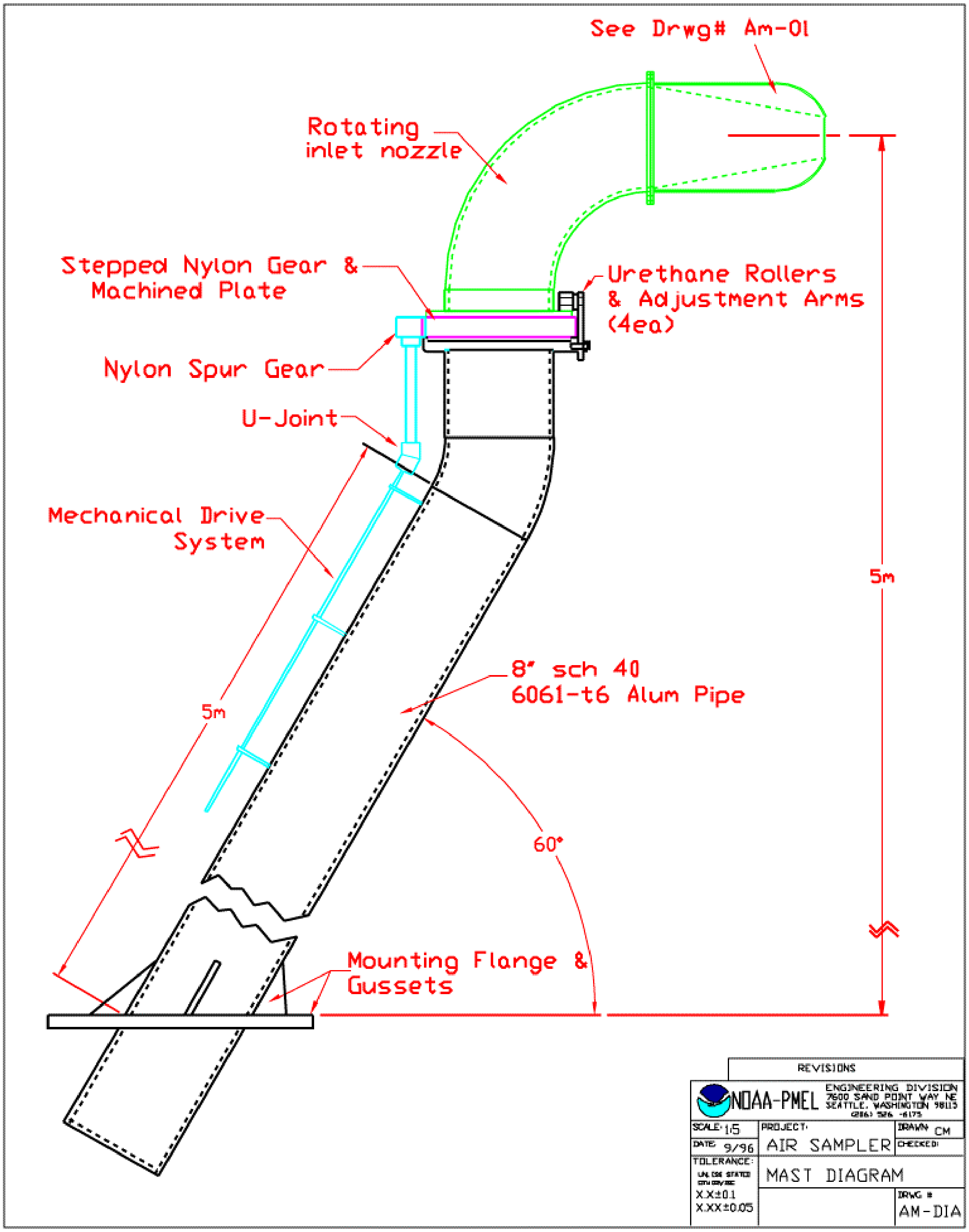
Shipboard measurements during the 2001 ACE-Asia intensive field operations (http://saga.pmel.noaa.gov/aceasia/us_ship.html) will contribute to the regional characterization of aerosol properties by providing data downwind of the continent. Ship operations will be directed to sample regional aerosol features (e.g. dust outbreaks, urban and industrial plumes) under different synoptic meteorological patterns and at various distances from shore. The goals of the shipboard studies are to:

- determine the physical, chemical and optical properties of the aerosol in the ACE-Asia region and assess the regional and temporal (diurnal to multi-day) variability of these properties,
- assess the major processes controlling the oxidation mechanisms of aerosol precursor gases and the formation, evolution and deposition of aerosol particles, and
- quantify the effect of the combined natural and anthropogenic aerosol on the region's radiation budget.

To accomplish these goals it is essential that we characterize the chemical, physical and optical properties of all particles in the radiatively important size range (approximately 0.1 to 10 um diameter, see figure1, Quinn et al., 1996). Super-micron diameter aerosols will be an important component in the ACE-Asia region due to both sea salt and mineral dust. Ideally we would like to sample this size range with 100% efficiency, but at a minimum we need to characterize the sampling efficiency of our inlet for particles within this size range. With a relative wind speed on the ship ranging from 3 to 20 m/s, near-isokinetic sampling of the free airstream is certainly easier than on an aircraft (Huebert et al., 1990; Sheridan and Norton, 1998). We hypothesize, therefore, that our ship aerosol sampling mast will efficiently pass particles in the 0.1 to 10 um diameter size range. However, to reduce our uncertainties in relating in-situ and columnar (satellite, sun photometer, radiometer) measurements we propose here to test the transmission efficiency of the ship aerosol sampling mast.

Characteristics of current the ship aerosol sampling mast:

Aerosol particles are sampled through a heated mast that extends 5 m above the aerosol measurement container (see figure). The mast is capped with a cone-shaped inlet nozzle that is rotated into the relative wind to maintain nominally isokinetic flow and minimize the loss of supermicron particles. Air is drawn through the 5 cm diameter inlet nozzle at 1 m^3 min^{-1} and down the 20 cm diameter polyester-based powder-coat aluminum mast. The lower 1.5 m of the mast are heated to dry the aerosol to a relative humidity (RH) of 55 ± 5%. This allows for constant instrumental size cuts through variations in ambient RH. Fifteen 1.9 cm diameter electrically conductive polyethylene or stainless-steel tubes extend into this heated zone to direct the air stream at flows of 30 l min^{-1} to the various aerosol sizing/counting instruments and impactors. A theoretical analysis of the collection efficiency of the inlet nozzle (Hinds, 1982) showed that, for the range of non-isokinetic conditions resulting from a factor of two variation in wind speed compared to the isokinetic design speed of 8 m/s and a 30 degree axial deviation, the under- or over-sampling of 14 um particles was less than 10%. Similar calculations for the flow divider at the base of the mast indicated a sampling efficiency for 10 µm particles of about 90%. For smaller particles the sampling efficiencies are closer to 100%. Comparisons of the total particle count (Dp > 3 nm) during intercomparisons with the NCAR C-130 and ACE-1 ground stations agreed to within 20% suggesting minimal loss of particle number in the inlet system (Weber et al., 1999). A similar comparison with the NCAR C-130 during INDOEX showed agreement to within 5%. Assessing the inlet efficiency for larger particles is more difficult. Comparisons of marine boundary layer particle extinction based on in situ measurements and total column measurements (NASA Ames suntracking sunphotometer) during ACE-2 agreed to within the uncertainties of the measurements and calculations, however those uncertainties are quite high (Livingston et al., 2000; Schmid et al., 2000). We will not be able to reduce these uncertainties without characterizing the transmission efficiency of the inlet for particles in the 0.8 to 10 um diameter size range.



See Drwg# Am-01
Rotating inlet nozzle
Stepped Nylon Gear & Machined Plate
Urethane Rollers & Adjustment Arms (4ea)
Nylon Spur Gear
U-Joint
Mechanical Drive System
5m
8" sch 40 6061-t6 Alum Pipe
5m
60°
Mounting Flange & Gussets
REVISIONS
NOAA-PMEL
ENGINEERING DIVISION
7600 SAND POINT WAY NE
SEATTLE, WASHINGTON 98115
SCALE: 1:5
PROJECT:
DRAWN: CM
DATE: 9/96
AIR SAMPLER
CHECKED:
TOLERANCE:
X.X±0.1
X.XX±0.05
MAST DIAGRAM
DRWG #
AM-DIA

Statement of Work:

1. Aerosol transmission efficiency tests

Scientific questions:

1. What is the transmission efficiency of the aerosol inlet for particles in the 0.8 to 10 um diameter size range through the sampling mast?
2. How does wind speed affect this efficiency?
3. How does the flow down the mast affect this efficiency?
4. How does the mast angle (angle between the wind direction and inlet nozzle orientation) affect the efficiency?

The sampling mast will be mounted in the Kirsten Wind Tunnel at the University of Washington (http://www.aa.washington.edu/uwal/uwal.html). The Kirsten Wind Tunnel is a subsonic, closed circuit, double return wind tunnel. The tunnel has a test section with a rectangular 8' x 12' cross-section that is 10 feet long. Two sets of 14' 9"-diameter seven-bladed propellers move the air up to 200 MPH through the test section. We propose to test the mast at wind speeds ranging from 20 to 40 MPH. Polyethylene glycol (PEG) aerosol particles will be generated using a pressurized tank and spray nozzle. PEG particles were chosen based on discussions with wind tunnel personnel. Although NaCl particles would have better simulated oceanic sampling conditions, concern about corrosion in the wind tunnel precludes their use. The mast will be mounted under the wind tunnel with the rotating top cone extending into the wind tunnel. Aerosol size distributions will be measured using two matched TSI Aerodynamic Particle Sizers. After comparing the two instruments side-by-side in the wind tunnel, one APS will be mounted in the tunnel with a 30 cm isokinetic inlet pointed into the wind. The APS will be located immediately adjacent to, and slightly behind the mast inlet. The second APS will be mounted at the base of the mast connected to one of the 15 sampling tubes. The data will be recorded and displayed in real time. Tests will be conducted at different wind speeds, mast angles, and mast flow rates.

2. Construction of second sampling mast, laboratory container and pump container

Based on the results from the mast efficiency tests, a second sampling mast will be constructed. An anemometer mounted on top of the mast will provide wind speed and direction data that will be used to control a motor to rotate the cone-shaped inlet nozzle into the relative wind. A blower will be used to pull approximately 1 m^3/min of air down the 20 cm diameter mast. Fifteen 1.9 cm tubes will extend into the lower 1.5 m of the mast to subsample the air stream for various aerosol instruments. These dimensions and flows will be optimized based on the wind tunnel tests. Our current mast will be modified if needed. Our goal is to have two identical sampling inlets so that measurements in the two containers will be directly comparable.

The mast will be mounted on the top of a 20' laboratory container. The 20' laboratory container will be insulated and equipped with Unistrut on 2' centers to provide secure mounting for instrumentation. A foyer inside the large double doors will house the air conditioner and transformer (needed to reduce the 480v ship power to 220/110 V). Electrical power and lighting will be distributed around the laboratory. Optical windows, provided by Judd Welton (NASA-GSFC) will be installed in the roof and container side for use by a micropulse lidar. A data acquisition board will be included in an instrument rack to provide the capability to record analog signals on either the ship or PMEL data logging systems. A computer terminal will display the logged PMEL data (meteorological data, position, oceanographic data, CN counts, sample flow rates etc.)

The 12’ pump container will obtain 220v electrical power from the laboratory container transformer. The air conditioned container will have electrical outlets for up to 20 sampling pumps. A data acquisition board will be included in an instrument rack to provide the capability to record analog signals on the PMEL data logging system. A computer terminal will display the logged PMEL data (meteorological data, position, oceanographic data, CN counts, sample flow rates etc.). An analog signal from the PMEL sector controller will be available to control pump sampling.

Summary:

Several benefits will be derived from this work.

- The added sampling/pump space will allow more research groups to participate aboard the ship and will thus allow us to more fully characterize aerosol properties and assess the processes controlling those properties.
- The addition of a second identical sampling mast will mean that all in-situ aerosol instruments are sampling the same aerosol population, collected from the same height above sea-level, at the same location on the ship, and at the same flow rate. Our data sets should therefore be directly comparable which will allow us to assess the internal consistency of our data set.
- Quantifying the transmission efficiency of the inlet is critical for comparing the ship data with other platforms and for comparing the in-situ measurements with column integrated aerosol and radiation measurements.

References:

Anderson, T.L., and J.A. Ogren. Determining aerosol radiative properties using the TSI 3563 Integrating Nephelometer, *Aerosol Sci. Technol.*, 29, 57-69, 1998.

Anderson, T.L., D.S. Covert, J.D. Wheeler, J.M. Harris, K.D. Perry, B.E. Trost and D.J. Jaffe. Aerosol backscatter fraction and single scattering albedo: measured values and uncertainties at a coastal station in the Pacific NW, *J. Geophys. Res.*, 104, 26,793-26,807, 1999.

Bates, T.S., Preface to the Second Special Section on the Southern Hemisphere Marine Aerosol Characterization Experiment (ACE 1). *J. Geophys. Res*., 104, 21,645-21,647,1999.

Bates, T.S., B.J. Huebert, J.L. Gras, F.B. Griffiths, and P.A. Durkee, International Global Atmospheric Chemistry (IGAC) Project's First Aerosol Characterization Experiment (ACE 1): Overview, *J. Geophys. Res.*, 103, 16,297-16,318, 1998a.

Bond, T.C., T.L. Anderson and D. Campbell. Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols. *Aerosol Sci and Technol.*, 30, 582-600, 1999.

Hinds, W.C., *Aerosol Technology*, Wiley, 1982, chapter 10, p 191, formula 10.7

Huebert, B.J., G. Lee, and W. Warren, Airborne Aerosol Inlet Passing Efficiency Measurement, *J. Geophys. Res.*, *95*, 16369-16381, 1990.

IPCC, Climate Change 1995: The Science of Climate Change, Intergovernmental Panel on Climate Change, Cambridge University Press, 1996. Editors: J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg and K. Maskell, 1996.

Jaffe, D., T. Anderson, D. Covert, R. Kotchenruther, B. Trost, J. Danielson, W. Simpson, T. Berntsen, S. Karlsdottir, D. Blake, J. Harris, G. Carmichael, and I. Uno. Transport of Asian Air Pollution to North America, *Geophys. Res. Lett.*, 26, 711-714, 1999.

Livingston, J.M., V. Kapustin, B.Schmid, P.B. Russell, P.K. Quinn, T.S. Bates, P.A. Durkee, P.J. Smith, V. Freudenthaler, D.S. Covert, S. Gasso, D. Hegg, D.R. Collins, R.C. Flagan, J.H. Seinfeld, V. Vitale, C. Tomasi. Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE-2 and comparison with selected land, ship,aircraft, and satellite measurements, *Tellus*, in press, 2000.

Quinn, P.K., V.N. Kapustin, T.S. Bates, and D.S. Covert. Chemical and optical properties of marine boundary layer aerosol particles of the mid-Pacific in relation to sources and meteorological transport. *J. Geophys. Res*., 101:6931-6952, 1996.

Raes F., T.S. Bates, F. McGovern and M. Vanliedekerke The second Aerosol Characterization Experiment (ACE-2): Overview. *Tellus*, in press, 2000.

Schmid, B., J.M. Livingston, P.B. Russell, P.A. Durkee, H.H. Jonsson, D.R. Collins, R.C. Flagan, J.H. Seinfeld, S. Gasso, D.A. Hegg, E. Ostrom, K.J. Noone, E.J. Welton, K.J. Voss, H.R. Gordon, R. Formenti, and M.O. Andreae. Clear-sky closure studies of lower tropospheric aerosol and water vapor during ACE-2 using airborne sunphotometer, airborne in-situ, space-borne, and ground-based measurements. *Tellus*, in press, 2000.

Sheridan, P.J., and R.B. Norton, Determination of the passing efficiency for aerosol chemical species through a typical aircraft-mounted diffuser-type aerosol inlet system, *J. Geophys. Res.*, 103, 8215-8226, 1998.